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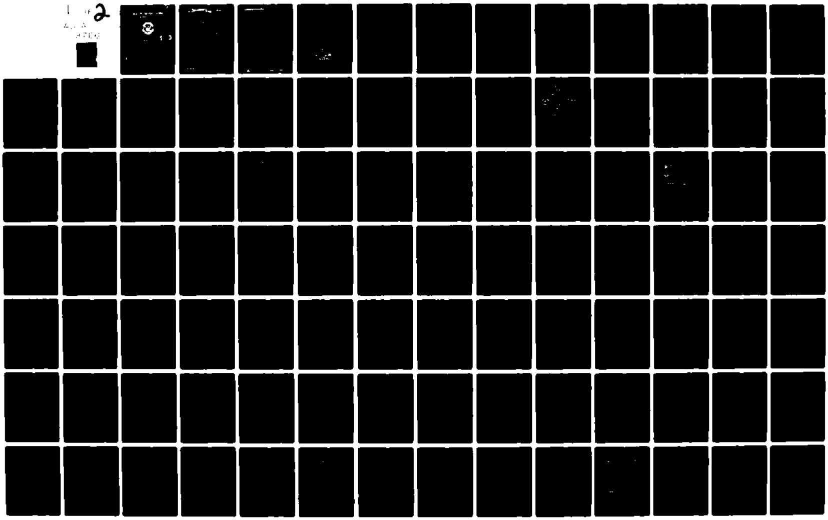

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

IMPACT OF VHSIC TECHNOLOGY ON BATTLE ZONE MATERIAL MANAGEMENT

by

Thomas Hewitt Hicks

June 1982

Thesis Advisors: J.W. Creighton
Lonnie G. Pollard

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A new era in military microelectronics is unfolding. The Department of Defense, in 1979, initiated a six-year tri-service Very High Speed Integrated Circuits (VHSIC) Program that will develop a new technology base for integrated circuits. This program has the potential of producing systems-on-a-chip capability. VHSIC, with its high density circuits, promises drastic reductions in size, weight, and power requirements, while still yielding higher levels of reliability and performance. The impact of this technology on systems capabilities and

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) availability offers solutions to many logistics support problems. This thesis explores the impact of VHSIC technology on material management and logistics support in the battle zone of the future with a focus on maintenance and systems capabilities enhancement attributes and how they will facilitate the logistics process in the highly intensified combat promised for the future.

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Impact of VHSIC Technology on Battle Zone Material Management

By

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Major, United States Marine Corps
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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

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June 1982

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ABSTRACT

A new era in military microelectronics is unfolding. The Department of Defense, in 1979, initiated a six-year tri-service Very High Speed Integrated Circuits (VHSIC) Program that will develop a new technology base for integrated circuits. This program has the potential of producing systems-on-a-chip capability. VHSIC, with its high density circuits, promises drastic reductions in size, weight, and power requirements, while still yielding higher levels of reliability and performance. The impact of this technology on systems capabilities and availability offers solutions to many logistics support problems. This thesis explores the impact of VHSIC technology on material management and logistics support in the battle zone of the future with a focus on maintenance and systems capabilities enhancement attributes and how they will facilitate the logistics process in the highly intensified combat promised for the future.

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I. INTRODUCTION

A. GENERAL

The complexity of providing logistics support for deployed forces has escalated substantially in recent years. System failures resulting from the complexity have been increasing, and are predicted to continue to increase further unless deliberate actions are taken to reverse the trend.

New types of weapon systems are emerging that will alter the application of military force in the battle zone. These new systems will impact greatly on the balance of military power for many years to come.

The driving force behind these systems is a force multiplier concept that will optimize the selection, time, and precision application of fire power to reduce any numerical disadvantages in systems and personnel that the U.S. military forces could encounter on the battlefield of the future. This concept relies greatly on improved target acquisition and precision guided munitions.

The equipment to be used in future battle management systems include long range radars, special receivers, secure high data rate communications equipment, high resolution radar, optical sensors, high precision navigation and target acquisition systems, precision guided munitions, and equipment control devices, including remote control.

All of the above equipment makes intensive and extensive use of signal and data processing components. To pack all of these capabilities into small packages requires them to be compact, lightweight, reliable, low powered and fairly inexpensive. The Department of Defense's Very High Speed Integrated Circuits Program (VHSIC) has the potential for high impact on logistic support and material management in the battle zone of the future.

VHSIC technology will impact on operational equipment and the maintenance of that equipment. It is applicable to air, sea, ground platforms. It can enhance the capabilities of almost all systems either directly or indirectly. The application of VHSIC technology will advance lethality, target acquisition, and mobility to unparalleled levels. Its capability enhancing applications provide a solution to tactical and technological demands of the future battle zone.

VHSIC technology when applied will bring about dramatic improvements in the availability and operational readiness of signal and data processing related systems. The high integration level of VHSIC can bring about a 10 to 100:1 improvement in reliability. The proposed built-in-test (BIT) features can have marked impact on testability and can greatly simplify maintenance procedures resulting in higher maintainability of systems. The projected fault-tolerance designs of VHSIC components offer another order of magnitude to improve the reliability of systems. The synergistic effects of VHSIC's impact on reliability and maintainability will bring about positive changes in maintenance concepts and will drastically affect battle zone logistics requirements for electronic systems and systems that utilize integrated circuits in their subsystems.

Resulting from VHSIC applications will be operational equipment that is more reliable and expendable, and for munitions, more effective per round/sortie. Thus more battle can be waged with a given flow of material to the battle zone. Maintenance of equipment can be reduced through reliability and testability and the resulting equipment failure will be reduced as will be the spares to replace and repair. VHSIC technology can be applied to the material management problem itself. Computerized equipment can be deployed down to the company level on a near real-time basis to improve the efficiency of material distribution. The logistician should be able to put the right things in the right place, at the right time more efficiently and effectively than ever before.

B. OBJECTIVE AND SCOPE

The objectives of this thesis are to:

1. Increase the awareness of the reader in the area of current and future trends in microelectronic application to logistics.
2. Examine the impact of VHSIC technology on material management in the battle zone of the future.

This thesis investigates the Department of Defense's VHSIC program with a focus on VHSIC's attributes impacting on logistical support on the battlefield of the future. More specifically, the discussion focuses on the direct and indirect enhancement of battle zone systems capabilities offered by VHSIC and the operational readiness impact of VHSIC's maintenance attributes.

C. METHODOLOGY

Material to support this work was obtained from written material relating to VHSIC technology. This included technical reports, magazine and journal articles, studies, analysis, and related theses. Interviews and visits were made at Boeing Aerospace Company, Seattle, Washington, and Naval Weapons Center, China Lake. Telephone conversations and interviews were conducted with D. W. Burlage, DOD Deputy Director of VHSIC program, T. Lindgren, Deputy Director of Navy VHSIC Program, P. H. Hudson, VHSIC Project Officer Army Electronic Technology and Devices Laboratory, R. L. Remski, Air Force VHSIC Program Office, and representatives from Naval Ocean Systems Center, Naval Avionics Center, Naval Air Development Center. All of the above organizations provided research material, oral and written. The material was analyzed with an intent to discover how VHSIC technology will impact on battle zone material management. During the investigation it was hypothesized that VHSIC's major impacts in logistics would be in the area of maintenance and the enhancement of systems capabilities. As a result, a particular emphasis was placed on describing and analyzing the impact of VHSIC technology on material logistical support in the battle zone of the future.

D. ORGANIZATION

This thesis is designed to provide the reader with an introduction to the VHSIC Program and a discussion of VHSIC idiosyncracies in the context of their potential applications, as well as conclusions and recommendations for further research.

Chapter I describes the urgency of solving logistics support problems and the need for recognizing the impact of technology and systems complexity upon operational readiness of military forces.

Chapter II provides a synopsis of the VHSIC program for those not familiar with its origin and progress to date.

Chapter III examines the present systems identified for initial applications of VHSIC and provides an overview of possible applications of VHSIC in many areas and focuses on its impact for enhancing the logistical process on the battlefield.

Chapter IV examines the impact of VHSIC technology on systems maintenance with a focus on reliability, availability, and maintainability.

Chapter V discusses the implications of implementing VHSIC technology within the framework of battlefield material management.

Chapter VI provides the summary, conclusions, and recommendations for further research. Appendix A provides a glossary of key terms and a list of acronyms which are relevant to the VHSIC program and are used throughout this thesis.

II. A DESCRIPTION OF THE VHSIC PROGRAM

A. BACKGROUND

Design of battlefield systems must be based upon the premise of maximizing destructive capability while minimizing system resources. Future tactical systems will require highly sophisticated embedded processing systems with ultra fast response times. The application of very high speed integrated circuits to systems will facilitate the achievement of these objectives.

In the 1950's it became obvious that a new approach to electronic components for military equipment was needed and it was hoped that such an approach would offer improvements in reliability, reductions in size and weight, and reduced costs, while providing the same or increased levels of performance. In 1958 the Air Force introduced its molecular electronics. This concept used complete electronic circuits on blocks of semiconductor materials. Thus the integrated circuit (IC) era was launched.

In the early 1960's, with Autonetics application of integrated circuits to reduce the weight of Minuteman missiles, came the onset of rapid application of integrated circuits into future electronic systems.

By the end of the 1960's metal oxide semiconductor (MOS) transistor technology was being used and in 1971 large scale integration in the form of 4-bit microprocessors was introduced. During the 1970's the military somewhat reduced its supportive role to the integrated circuit industry. As a result of this deemphasis in the mid-1970's, it became apparent that military electronics was lagging behind in microelectronic technology associated with integrated circuits.

After an extensive technical investigation it was found that application of large scale integration in military electronic systems had not been extensive and that advantages offered in terms of improved signal and data processing capabilities, reduced life cycle costs, greatly reduced size, as well as weight and power, had not been explored and exploited. Very large scale integration technology was explored and a new era in military electronics begun. During 1978 and 1979 the Department of Defense formulated its very high speed integrated circuits program (VHSIC) [Ref. 1].

B. RATIONALE AND OBJECTIVES OF VHSIC PROGRAM

The Department of Defense (DOD) initiated a major new program in high speed, high throughput signal and data processing in support of military electronic requirements for the mid-1980's and beyond. The program has been titled Very High Speed Integrated Circuits (VHSIC), emphasizing its significant relationship to integrated circuit technology, as well as the need for higher speed processing capability.

DOD, in conjunction with the industrial and scientific communities, is attempting, on a highly accelerated basis, to establish and exploit new and very promising plateaus of electronic technology. This effort will vastly expand technological opportunities for the design of low cost, high performance, and high reliability equipment. In this concerted thrust VHSIC will provide significantly advanced weapons and supporting systems capabilities in the late 1980's and early 1990's to cope with the growing Soviet technological threat and the new dynamics of future war.

Following are reasons for the establishment of the VHSIC program:

1. Reverse the erosion of U.S. electronic technology lead
2. Increase exploitation of IC technology advances
3. Focus development efforts on military requirements.

The specific objectives of the program include:

1. Acquisition of advanced signal/data processing capabilities for military systems
2. Provision of chips meeting military specifications
3. Reduction of technology insertion gap
4. Reduction of acquisition and life cycle costs [Ref. 2].

Successful completion of the VHSIC program are intended to provide DOD with the following specific goals:

1. Provide critical electronic subsystems required to meet military shortcomings expected in the mid-1980's and early 1990's
2. Retain and extend the U.S. technological lead in advanced military electronics
3. Reduce life cycle costs associated with military electronic systems
4. Avoid a severe future problem if advanced IC's are not used in military systems [Ref. 2].

The VHSIC program differs significantly from the broad commercial very large scale integration (VLSI) thrust in integrated circuits in the following respects:

1. There is a major emphasis on the development of IC's for broad classes of military systems, to develop technology and deliver functions with no existing need in industry.
2. There is a major emphasis on increasing real-time system throughput which requires not only higher chip complexity, but also higher clock rates to achieve a capability for real-time processing.
3. There is a major emphasis on achieving new architectural concepts which minimize the need for design customization.
4. There is a major emphasis on military environmental requirements such as performance over a wide

temperature range, radiation exposure, and reliability.

5. There is need for exploitation of the higher chip complexity available to achieve a capability of built-in-test (BIT) and fault tolerance with significantly improved reliability and mean time to repair (MTTR) [Ref. 3].

The VHSIC efforts are taking advantage of leverage provided by the larger commercial VLSI activity, while concentrating on those technology tasks essential to achieving military goals.

C. PROGRAM MANAGEMENT

VHSIC is a joint Army/Navy/Air Force program with DOD oversight. The program management structure is shown in Figure 2-1. Figure 2-2 provides the members and responsibilities of the Executive Committee. The Steering Committee, which is chaired by the VHSIC Program Director, has the following responsibilities:

1. Program planning
2. Organization
3. Implementation
4. Evaluation
5. Laboratory coordination

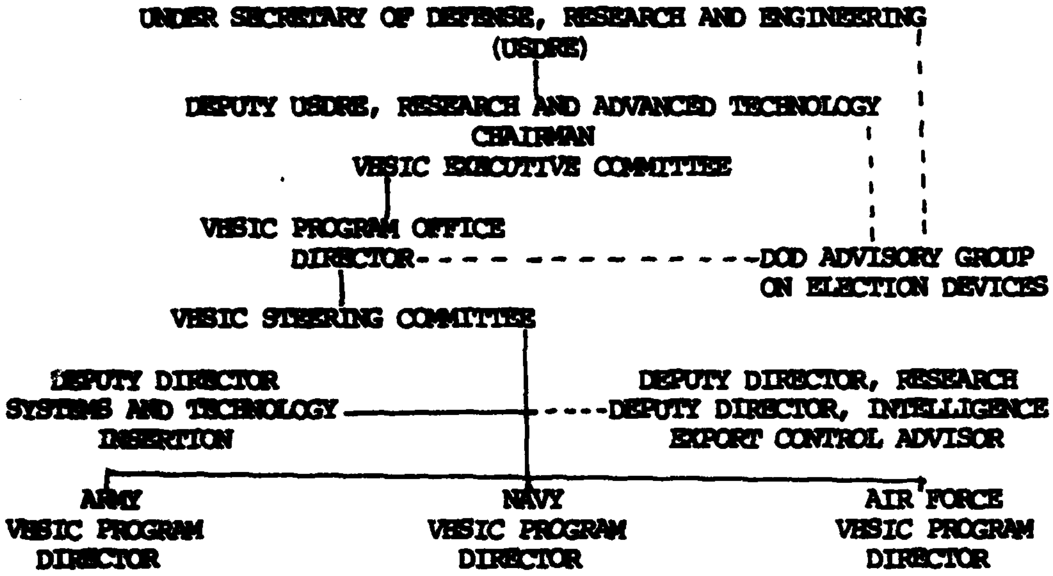

Figure 2.1 - VHSIC Management Structure

RESPONSIBILITIES:	ESTABLISH BROAD POLICY AND OVERALL OBJECTIVES
CHAIRMAN:	DEPUTY UNDER SECRETARY FOR DEFENSE, RESEARCH AND ADVANCED TECHNOLOGY
VICE-CHAIRMAN:	DIRECTOR ELECTRONICS AND PHYSICAL SCIENCES
EXECUTIVE SECRETARY:	VHSIC PROGRAM DIRECTOR
MEMBERS:	ASST. SECRETARY OF THE ARMY, RDA* ASST. SECRETARY OF THE NAVEY, RE&S* ASST. SECRETARY OF THE AIR FORCE, RD&L* DIRECTOR, DARPA* DIRECTOR, NSA* DIRECTOR, DNA*
EX OFFICIO MEMBERS:	DUSD (S&SS), DUSD (TWP) DUSD (C^3I), DUSD (ACQUISITION POLICY) DUSD (IPT)

*OR DESIGNATED REPRESENTATIVE

Figure 2.2 - VHSIC Executive Committee

6. Intelligence assessment

7. Technology transfer

8. Control of critical technology

The VHSIC Program office has the following responsibilities:

1. Implement responsibilities of VHSIC steering committee

2. Coordinate VHSIC with major related thrusts of intelligence agencies

3. Develop strategy for control and timely transfer of VHSIC technology to avoid premature release

4. Provide guidance for financial management of VHSIC to assure that expenditures are supportive of goals and objectives.

The VHSIC management structure, which is a strong tri-service effort, will effectively and efficiently pull together the diverse disciplines and activities involved to execute the VHSIC program [Ref. 2: p. 199].

D. VHSIC GOALS

The goals of the VHSIC Program are categorized into five major areas:

1. To increase the functional throughput rate from the current (1.5×10^{11} gate Hz/cm^2) to (5×10^{11} gate Hz/cm^2) in Phase I to (10^{13} gate Hz/cm^2) in Phase II

2. Technology transparency to enable easy insertion of the new technology into existing and developing systems

3. Radiation tolerance dose: 10^4 rad(SI), dose rate: 10^8 rad (SI)/S, neutrons: $10^{11}/cm^2$

4. Availability in terms of obtainable application in any military system

5. Built-in-test at the chip level [Ref. 2: p. 199].

E. PROGRAM PLAN AND EXECUTION

The VHSIC Program is organized conceptually into four phases: Phases 0, I, II, III. Phases 0, I, II are being carried out consecutively, with Phase III being carried out in parallel with the other three. Program phases actually commenced in March of 1980 and are scheduled for continuation into 1986.

Phase 0 ("Program Definition") -- This phase covered program definition for Phases I and II. It was in effect from March 1980 through February 1981 as a study phase to define the detailed approach and the plans for achieving the final objectives of the VHSIC Program. It included the following:

1. Systems and subsystems analysis
2. Literature surveys
3. Partitioning studies
4. Designs layouts

5. Computer aided device modeling

6. Experimental fabrication

7. Testing of device designs, layouts, processing techniques.

In Phase 0 architecture and designs approaches were selected to implement VHSIC chips with 1.25 micrometer (Phase I) and submicrometer (Phase II) minimum feature size devices.

Phase I -- Phase I, which commenced during May 1981, covers development of complete electronic brassboard subsystems within three years. It is subdivided into two parallel efforts, Ia and Ib. Ia is scheduled to produce chips according to 1.25 micrometer minimum feature size with an equivalent gate-clock frequency product exceeding 5×10^{11} gate Hz/cm^2. It further includes a pilot line production capability for VHSIC chips. The feasibility of design tools and simulation aids and basic principles of design/architecture/software/testing (DAST) will be demonstrated during Ia. Phase Ib will consist of the initial efforts to extend IC technology to submicrometer feature sizes and corresponding circuit complexities. It will address broad problem areas in submicron fabrication and identify promising methods of approach. A key feature of Phase I will be the development of built-in-test technology.

Phase II -- Phase II will be directed toward developing all aspects of IC technology necessary for crossing into the submicron area. It will establish means to develop an advanced capability of producing militarized IC's designed around submicron rules. Phase II will have a fundamental consideration of minimizing customization. The concepts of fault-tolerance and built-in-testability will be required. Fundamental throughput rates of 10^{13} gates/second will be required of Phase II for successful completion of goals.

Phase III -- The VHSIC Phase III runs parallel with the main program with the purpose of providing diverse technology efforts which are relative in nature and supportive of Phase I and II. The areas of Phase III are architecture, lithography, design automation, materials, device technology, hybrid packaging/techniques, fabrication: macrocells and chips, reliability, testing characterization, and standardization. The above has provided an overview of the plan and some of the execution of the VHSIC Program as of this writing. The next section focuses on current priorities of the program [Ref. 4].

F. CURRENT EMPHASIS

The VHSIC Program has completed approximately one-third of its present six year program scheduled for completion in 1986. The goals and rationale of the program have been provided. The plan and its execution have been summarized.

What are the current program priorities that are now being emphasized? Technology insertion, according to the

VHSIC Program Office is of top priority. The program was structured for technology insertion from its inception. This emphasis must and will continue. As one of its insertion mechanisms, it utilizes a tri-service and DOD committee approach in operations. Each service has been tasked with the preparation of technology insertion plans. These plans are the services' proposals for implementation of VHSIC technology into their respective systems.

The program's structure also lends itself to technology insertion with the incorporation of system drivers with vertical integration. The brassboard subsystem developments and demonstrations required are structured for technology insertion. The VHSIC contractors are required to provide technology insertion plans as well as the three services.

The preliminary technology insertion results are that applications for current operational systems and equipment where VHSIC chips can be inserted to provide cost, size, weight, and reliability advantages have been identified. The new VHSIC-derived performance functions that can be added to existing systems and equipment have been identified. Systems and equipment in development, which can use VHSIC technology, have been identified for planned upgrades. New systems and equipment capabilities that were not developed before because of technological limitation have been identified.

As of this writing, funded brassboards impact more than 35 systems and more than 60 systems have been identified upon which VHSIC technology will have an impact. This appears only to be the beginning. Almost any system that employs electronics could be impacted by VHSIC. A detailed examination of VHSIC impact on systems will be presented later.

Another area of current emphasis is acquisition policy. As the program progresses evaluations are being made in regard to the contractors and their meeting of performance standards. Selectivity in the allocation funds will be practiced. Once the process technologies are refined funds can be channeled into product technologies. This is one of the driving forces in the present acquisition policy emphasis.

The current emphasis on interoperability of VHSIC components with other systems is required so that the increased effectiveness and utilization of VHSIC circuits are optimized. This requirement will foster a synergistic effect in the combining of VHSIC performance features with the performance features of existing systems. Standardization will be a cornerstone in the VHSIC construction plan.

According to the VHSIC program office an area that is receiving much emphasis and question in VHSIC systems is that of maintenance-free operation. Maintenance-free electronic systems are those that will have built-in testing capabilities, can detect and correct faults or tolerate them with few ill effects, and which can reconfigure themselves to continue operation in spite of a partial failure. According to Dr. Donald Burlage, Deputy Director DOD VHSIC Program, there is a compelling need for improvement in availability, usability, and affordability in electronics. VHSIC's high integration level can cause a 10 to 100:1 improvement in reliability. Dr. Burlage says that Built-In-Test (BIT) could greatly simplify maintenance procedures and reduce life-cycle-cost(LCC). Also in conjunction with maintenance-free electronics is the fact that the fault tolerance designs of VHSIC can offer another order of magnitude of improvement in reliability and in turn further reduce the LCC of electronic systems. The environmental hardening that is required in VHSIC will insure it functioning when and where the system or subsystem is needed.

Application expansion also is currently being emphasized and will gain more emphasis as the program progresses. During Phase 0 some 70 different VHSIC brassboards were proposed. These covered a multitude of potential applications. Phase I commenced with the selection of 6 of the 70 proposals. This leaves a large and full reservoir of applications that are waiting for the maturation of VHSIC technology.

The above current emphasis will surely change as VHSIC technology matures and the technology transfer process takes place. This program is charting on familiar but unsure waters which promise to bring untold and incomprehensible benefits. The success of this program promises and projects many substantial enhancements of systems effectiveness.

III. VHSIC CAPABILITY-ENHANCING APPLICATIONS

A. WHAT CAPABILITIES ARE NEEDED?

VHSIC technology has awesome potential for enhancement of military system capability, specifically those systems utilizing signal and data processing devices and equipment.

The need for high throughput, high speed integrated circuits exists in many areas. The battlefield commander needs more information on as many of the variables of the battlefield as possible. This need is the basis for VHSIC utilization in target acquisition and battlefield exploitation. There is convincing evidence that the potential adversaries have superior quantities of weapon systems. The U.S. battlefield commander needs a force multiplier; that is, he needs extremely accurate weapons, thus more lethal weapons because of the limited quantities available to him. According to Dr. Edward Teller, there is considerable evidence that U.S. military acquisition strategy is quality not quantity. The objective appears to be to produce few weapons systems in few numbers with multiple functions, vast capabilities, and great versatility. This strategy, combined with the adversary's possession of quantitive advantages is a driving force behind the utilization of technology as a force multiplier. VHSIC technology will be a force multiplier in its impact on operational equipment in terms of accuracy, lethality, mobility, and versatility. VHSIC has the potential to provide a solution to the problem of quality versus quantity [Ref. 5].

The need for signal and data processing equipment with speeds such that military threat reaction decisions can be made in real-time is unquestioned for the scenarios of the future battlefield. The military can not afford to fight tomorrow's wars with yesterday's technology. Potential adversaries have made major advances in microelectronics as has been demonstrated in systems used in the 1967 and 1973 mid-East wars and in 1972 in Vietnam. The potential enemy not only has quantity but also is rapidly developing quality. There is an intensified requirement to develop mechanisms that will efficiently and effectively allocate scarce assets against numerically superior forces [Ref. 6].

Just as there has been optimization of systems in other disciplines there is a valid and pressing need to centralize decision making for optimization on the battlefield. To accomplish this, there is needed a battle management system that is complemented by a detailed weapons assignment and engagement system.

The above system must be secure, reliable, jam-resistant, high capacity, and high speed. Vastly improved electronic subsystems are needed to meet the challenges of the sophisticated, high mobility future battlefield. The criticality of identifying the critical targets and concentrating attacks on these targets can not be overemphasized. To meet this requirement requires vast quantities of sensor data. This vast quantity of data needs immediate analysis to provide the commander with a projection of the enemy's intentions and patterns and in such speed that he can react in a timely triumphant manner. In combat, because of the complex interaction of sensors, data links, processing and fusion centers, location systems, and command guided weapons under the most stressful conditions, there must be capable, smooth working analytic devices.

To intercept and destroy enemy forces at sea, the fleet must possess all weather day and night capability. It also must mass attack assets that are coordinated and complemented with aircraft and missiles. A target assignment system is needed to optimize the total defense system by maximizing the utilization of its subsystems [Ref. 7].

The destruction of targets on land and/or at sea, which is dependent upon the scenario and maturation of the conflict, places increasing demands on the versatility of systems. The tactical strikes forces need not only all weather day and night capability, but also the ability to identify targets in dense environments with precision target tracking/attacking capabilities.

In the area of avionics, the major requirements are as follows:

1. Increased ranges
2. All weather day/night operations
3. Sophisticated IFF capabilities
4. Improved jam-resistance
5. Information correlation
6. Austere maintenance
7. Reduced weight and size
8. Reduced power and cooling
9. Increased capacity [Ref. 7].

The United States must rely on its technological superiority to meet its defensive and offensive missions against superior ground forces. According to Rand Report R-1643-PR, in the development of tactical air and ground systems to meet the threat offensively and defensively, the following capabilities are needed:

1. Maintenance of air superiority over battle area and in the zones behind the battle lines
2. High accuracy in air-to-ground weapon delivery with guidance from standoff platforms or with terminal guidance by the weapons themselves

3. Suppression of enemy air-defense systems through electronic countermeasures and air-to-ground weapons
4. Nighttime and all-weather operations
5. Accurate land, sea, or air battle area surveillance, and detection and tracking of enemy weapon systems; real-time data readout to command and control system
6. Rapidly reacting command and control systems for planning, directing, and coordinating tactical operations.

To become operational the above requires increasing use of digital signal processing and digital computer technology [Ref. 8]

All of the above needs point in the direction of integrated circuit technology, specifically to very high speed integrated circuits employed on a very large scale basis. The VHSIC program has come on-line with fulfilling the above needs as one of its major objectives. The yield from VHSIC technology in improving accuracy and in turn lethality by providing smaller, more capable on-board and/or embedded guidance and targeting computers will be awesome. The versatility that VHSIC speed and computing power will make available to weapons fosters the expansion of existing or planned systems to take on many new missions and functions.

B. INITIAL VHSIC APPLICATIONS TO MEET CAPABILITY NEEDS

According to Glenn Preston of Institute for Defense Analysis, presently the VHSIC program is concentrating on the following areas:

1. Target recognition
2. Spread spectrum waveform processing
3. Adaptive beam forming
4. Multi-sensor correlation
5. Moving target doppler processing
6. High resolution ground mapping
7. Signal integration
8. Sorting and parameter analysis
9. Moving target tracking
10. Image processing
11. Coding and decoding [Ref. 9]

Phase I of the VHSIC Program has resulted in some 20 candidates in which the VHSIC device will be developed. These system demonstration units are called brassboards. These units are being developed for initial application in certain functional areas and will demonstrate VHSIC's capability enhancement potential on systems.

These 20 candidates can be classified into six major functional categories: 1) command, control, and communications, 2) radar, 3) electronic warfare, 4) image processing, 5) general purpose computers, 6) antisubmarine warfare.

The processing functions involved with the above six functional categories are as follows:

1. Anti-jam modulation
2. Demodulation
3. Fast Fourier transforms
4. Adaptive moving-target indicators
5. High speed analog/digital conversion
6. Finite-impulse response filters
7. Programmable frequency synthesizers
8. Electronic counter-countermeasures
9. Programmable match filters
10. Vector arithmetic units [Ref. 10]

Figure number 3 provides the 20 brassboard candidates by functional area and respective service system involved [Ref. 11].

1. <u>Command, Control, and Communication</u>

In the functional area of Command, Control, and Communication there are four candidate systems. The first of these is the Joint Tactical Information Distribution System (JTIDS). It is an Air Force/Navy program with the purpose of developing a family of terminals and interfaces for integrated communication, navigation, and identification in tactical and air defense operations. This system will connect many different types of weapon systems, spread out over a very large area, with sources of surveillance,

COMMUNICATIONS, COMMAND, AND CONTROL

* JTIDS (AF)
* BIDS (A)
* A-J MODEM (N)
* NATO ID (N)

RADAR

* SURV (N)
* TAC (N)
* MRSP (AF)
* AMRAAM (AF)
* M^2F^2 (A)

ELECTRONIC WARFARE

* APMS (AF)
* TA/FC (A)
* ESM (N)
* MOBILE EW (A)

COMPUTERS

* GP (N)
* GP (AF)
* USSP (AF)

IMAGE PROCESSORS

* IMAGE PROC (N)
* AOSP (AF)
* CM (AF)

ANTISUBMARINE WARFARE

* ACOUSTIC SP (N)

VERY HIGH SPEED INTEGRATED CIRCUITS

Figure 3-1 Candidate VHSIC Systems Brassboards

intelligence and support information, weapon controllers, and decision making commanders. VHSIC components will provide modules which will perform one or more of the various processing functions. This application of VHSIC will simplify system integration through a standard interface. The high throughput rate of VHSIC will greatly enhance the capabilities of the system in terms of the volume and speed it will process information.

JTIDS will be linked to the Army's proposed system titled Battlefield Information Distribution System (BIDS). This system is a new generation of automated fire control, command and control, air defense, and intelligence gathering systems that require real-time, jam-resistant information distribution among a large number of users. VHSIC chips will be utilized in subsystem modules that will employ advanced signal processing and spread-spectrum modulation at rates in excess of 100 MHz. A VHSIC chip will be utilized for speech processing at rates as low as feasible with present technology.

One of the Navy's candidates, an anti-jam modem, will utilize a VHSIC chip set to fill the role of an all purpose modem that has programmability which will allow the same circuitry to serve many different sets of data modulation schemes (AM, FM, SSB, FSK, PN, etc.). This modem will be in the form of an add-on or insertion into existing communication systems greatly enhancing capacity and speed and maximizing anti-jam features.

The second Navy candidate is a chip set for a NATO Identification System (NIS) that is to be used by all military ships and aircrafts throughout NATO. This system will be compatible with all existing identification systems. VHSIC application will make marked improvements in the performance and reliability of this system.

2. Radar

Radar, the second functional area, has some five brassboard candidates. The first of these is a Navy surveillance radar. This system will have the capability to not only detect but help counter enemy missiles. The weight of the system should be around 460 kg. and have the processing rate of 4×10^{13} gate Hz.

Another radar candidate is a Navy tactical air radar signal processor. The requirements of signal processors in the next generation of fleet air defense aircraft will be very demanding on present technology. In fact it is felt that the demands can only be met with VHSIC technology.

The third candidate, under radar, is an Air Force multi-function radar signal processor to be employed in nose radar of high performance tactical aircraft. VHSIC components will be used in this system which has its initial application in the delivery of air-to-ground weapons. Future roles will be employment in air-to-air radar processing to include threat assessment.

The fourth radar candidate is the Air Force's advanced medium-range air-to-air system (AMRAAS). VHSIC components will provide the technology to overcome the present processing speed, memory, and analog/digital conversion limitations.

The Army's candidate for radar is the multi-mode Fire and Forget (M^2F^2) missile. The present technology will not meet the constraints of size, weight, power, and data processing speed requirements of M^2F^2 missile. This missile can be used in air defense and land combat employing several seeker modes. VHSIC will greatly enhance the versatility of this system.

3. Electronic Warfare

The third major functional category is electronic warfare with four candidates. The first candidate is to fill an Air Force need for an advanced power management system to improve airborne electronic countermeasures. VHSIC can drastically reduce the weight, size, and power requirements of this system and allow it to be employed with even greater capabilities than originally planned.

The Army has a planned signal processor for forward-looking infrared system (FLIR) to be used in the M-1 Abrams tank, remotely piloted vehicles, and other systems. The subsystem will provide hands-off automatic search and multiple target handling capability under degraded visibility battlefield conditions and will bring about improvement to airborne, anti-armor, and man-portable FLIR systems. Additionally, the above features in a micro-miniaturized device, suitable for an on-board RPV system will be combined with advanced image processing. This combination will allow covert data transmission, day and night surveillance, target acquisition, and designation of direct weapons fire. This system will notably enhance the target acquisition and fire control capabilities of the battle field commander. This system will meet the needs of the commander in the future dynamic battlefield. Weight, size, and power constraints are the driving forces in the development of this system. VHSIC components are mandatory if the capability of this system is to be optimized.

The Navy's electronic warfare candidate is an electronic support measures (ESM) signal sorter. The present sorters use some 1500 chips, but VHSIC can reduce the number to some 30 chips and still provide greater capability. The electromagnetic threat is increasing and better signal-sorting systems will be needed on aircraft, surface ships, and submarines. VHSIC components will provide the capabilities to meet the projected needs.

The Army also has a candidate system to provide electronic warfare weapons targeting. This system would be a passive, high-mobility integrated electronic-warfare system for real-time targeting and guidance information for attacking highly mobile, high-priority threats. This system must also be all weather and have on-board weapons guidance. The antenna will be of modular nature. VHSIC is a must if all of the above features are to be provided within the required power, weight, and size constraints.

4. Image Processing

The next functional area, image processing, has three candidates. The Navy will apply VHSIC components in a modular concept to solve image processor needs and provide the capability to use focal plane array technology for surveillance, weapon control, and signal processing.

The Air Force has a program called advanced on-board signal processor (AOSP). This program is to perform the signal processing functions on board satellites within the required power, life, radiation, size, and weight constraints. VHSIC components will be used to provide the capabilities and meet the processing requirements of multi-mission radar, electro-optical sensor, and advanced communication systems of this program.

The Cruise missile will be required to improve in many areas, specifically in the area of guidance control.

VHSIC devices can provide an autonomous precision navigation and guidance system that will reduce weight and improve survivability by allowing the missile to operate at much lower altitude, with greater maneuverability. This is an excellent candidate for the application of VHSIC technology to enhance the capabilities of an existing system that will be so vital on the future battlefield.

5. General Purpose Computers

In the area of general purpose computers there are three initial brassboards. The Navy will use VHSIC chips to produce smaller versions of existing computers with their application in torpedoes and F-14/18 carrier based fighters. These smaller versions will not only have the reduction of size, weight, and power but will also have greater capacity and much higher speeds. This will be a marked improvement over existing capabilities and will allow some design changes, internally and externally for the aircraft, torpedoes, and other systems that utilize computers.

The Air Force's initial application of VHSIC chips or devices in the area of general purpose computers is to shrink a general purpose airborne computer onto a VHSIC chip. This application in missiles with smaller, more powerful computers will greatly enhance the capabilities and could reduce the size or allow versatility and give the missile several additional missions to perform. The Air Force also has a universal sensor signal processor candidate that will be employed in the E-3A AWACS radar. The processor will be used in ECCM mission and will support sensors used in other programs such as advanced tactical radar, space radar, space/airborne electro-optical search systems, and unattended radar.

6. Antisubmarine Warfare

The final functional area of the brassboard candidates is antisubmarine warfare (ASW). The Navy will use VHSIC chip sets for programmable processing for ASW data. The applications will be in surface sonars, advanced sonobuoy array processors, and torpedoes. The application of VHSIC technology to this area will bring a new dimension to war at sea.

The above summarization of the VHSIC program and its application to meet some of the capabilities that are needed by the battlefield commander of the future is only the beginning of a new era in military electronics. VHSIC as discussed above can greatly enhance the capabilities of systems. The program is presently concentrating on these 20 candidates. There are numerous areas for VHSIC application expansion as indicated by the fact that only 6 of the 70 brassboards were selected. The next section will explore some of the further expansion of VHSIC application.

C. PROJECTIONS OF VHSIC APPLICATIONS

The added performance provided by VHSIC components will show significant improvements, either directly or indirectly, in systems and subsystems that utilize integrated circuits. The breadth of potential application of VHSIC is very significant. The application of improved digital integrated circuits to signal processing needs can be predicted for nearly all conceivable military systems. Some of the areas for exploration of VHSIC application are in long range radar systems, communications systems, high resolution radar and optical sensors, high precision navigation and target location systems, precision guided munitions, acoustic processing systems, battlefield material management systems, and battle management systems. This section will present some of the major areas that the author thinks are appropriate for this research, considering time constraints and the security classification of the applications utilizing VHSIC.

1. Command, Control, and Communication

As suggested earlier, VHSIC application is up to the imagination of the individual. In the area of Command, Control, and Communication systems, which are employed to plan and direct combat operations, maintain information on the status of the forces in the battle area, perform weapons and fire control functions, process and correlate sensor data, and handle communications, there are numerous applications for use of VHSIC.

What are some of the possible uses of VHSIC? One such application is in the Position, Location, Reporting System (PLRS). This system is to provide a real-time location on numerous air and ground units. VHSIC could greatly increase the mobility of subject system by reducing the size and weight by half. This would allow deployment down to the lowest possible level, even to a patrol. Also, VHSIC could enhance the anti-jam capability of this system substantially, making this system even more effective than when first designed. This system will provide the battlefield commander the precise location of all his equipment and personnel on the ground and in the air. VHSIC will have a notable impact on the mobility, versatility, control, and anti-jam capabilities of this system. This system, integrated with the Army's Battlefield Exploitation and Target Acquisition System (BETA), and other systems such as JTIDS and BIDS, will greatly enhance real-time decision making information required for future battlefield decision makers.

Another area for VHSIC application would be in man-packed radios utilized by ground forces. VHSIC has tremendous potential for small packages to enhance communications. Not only will the impact be in increased mobility but also the VHSIC chip can be employed to decrease interception through increased anti-jam and encryption capabilities. These features will allow a greatly increased application in units operating behind enemy lines. Also there is some indication, according to Rand report R-2377-ARPA of January, 1979, that units in future ground combat will be smaller. Dispersion, mobility, and versatility will be essential for operating on the future battlefield in an efficient and effective manner. VHSIC technology application in communication systems will facilitate these tactics.

In the area of avionics, there is a need to integrate communication, navigation, and identification into a small modular system for tactical aircraft. Additionally, this system needs to have the capacity to interact with satellite systems. VHSIC components will provide the capability and meet the size, volume, weight, and power constraints and also meet the complexity challenge of modems and signal processors that will be required to operate in multiple communication environment. VHSIC also can be employed in airborne and ground terminals that will be used in conjunction with this communication, navigation, and identification system. This projected application of VHSIC will greatly enhance the capability of tactical aircraft in their missions.

2. <u>Weapons Guidance and Control</u>

Future improvements in precision guided weapons will bring a new dimension to weapon lethality. Smaller, lighter, and more accurate munitions and missiles will be built that will have the same or greater damage effects. The destructive capability of units will increase drastically. The application of VHSIC in the control and guidance of weapons will have a quantum impact on lethality.

A future application of VHSIC is in the area of stand-off weapons and the target acquisition systems used in conjunction with these weapons. In the target acquisition area numerous opportunities exist for surveillance radar systems which could be employed with airborne systems. These systems could be used in RPV's, drones, or ship drawn kites and relay to ground or sea equipment vast amounts of data about enemy activity. This application would be employed in conjunction with an all sources fusion center that can process this data and provide commanders with real-time information they need. The integration of target acquisition systems, RPV's, and PLRS would provide vastly increased amounts of vital information to the commander. VHSIC components will also be employed in the analyzing and displaying of information. Computers, utilizing VHSIC components, will provide real-time information that will allow the commander to make more timely decisions. These decisions could have triumphant influences on the final outcome of a particular battle or an entire theater of war.

VHSIC chips applied to missiles will give them multi-seekers such as millimeter wave and infrared. This will improve the feature of lock-on after launch. Additionally, the capability to make mid-course and terminal corrections will be far more advanced than today. VHSIC components will allow further increases in accuracy in that image processing devices can be incorporated that will allow the system to seek out specific targets in a group of targets. VHSIC will vastly improve the selectivity of target acquisition by missiles after launch. The use of on-board microprocessors and microcomputers utilizing VHSIC components will further increase accuracy and lethality. All of these features can become reality through the use of VHSIC technology.

An inductive impact on lethality is the application of VHSIC chips in the employment of so called dumb weapons. The utilization of VHSIC technology for target recognition, location, identification and classification systems will allow more accurate delivery of dumb weapons. Therefore, an indirect impact of VHSIC will be the enhancement of the lethal capabilities of dumb weapons by insuring the target is valid and accurately located.

3. <u>Electronic Warfare</u>

The electronic warfare systems in tactical aircraft must detect illumination by the enemy, analyze the characteristics of the enemy radar, and take appropriate counter measures. The potential adversary is developing and refining air defense radars that continuously change transmission characteristics, making detection much more difficult. The threat environment of the future will consist of an increased density of highly advanced emitters, with waveforms that will include both frequency and time agility. These threats will be directed not only at airborne units, but also at ground and sea units. Because of the increasing sophistication and range of these weapons, the commander will need real-time information in order to assess and effectively counter the threat. VHSIC application in an EW computer to enhance the sorting and classifying of electromagnetic signals is an area for future expansion that will aid in meeting the threat. The use of VHSIC devices in ECCM systems and EW systems will be essential if the military is to keep up with the technological developments in these areas. The high-speed and capacity of VHSIC will meet the growing demands of signal and data processing in this critical area of the battlefield.

4. <u>General Purpose Computers</u>

There are numerous areas for the application of VHSIC components in computers. The present application of computers can be enhanced by the mobility, versatility, and capacity that VHSIC will offer. The weight, size, and power reduction features of VHSIC will bring hand-held computers to the battlefield. Data processing for intelligence, manpower, and logistics are very fertile areas for application. VHSIC can bring information automation to the battlefield in ways yet to be explored. VHSIC will allow signal and data processing in the most mobile packages. One such application would be the application of VHSIC chips to logistics needs. An area for possible exploration would be the storage of technical data in the equipment itself. A microcomputer/microprocessor employing VHSIC chips could maintain static and dynamic information on a vehicle, such as a tank, truck, etc., on other equipment such as radar, avionics, or on weapons systems such as missiles, aircraft, ships, and submarines. This system could hold maintenance data or parts requisitioning data. The capability will be available to the logisticians to develop and exploit to his greatest dreams.

In conjunction with this on-board data storage capability, VHSIC employed in microcomputers will allow automation of material management down to the lowest unit level in combat. An example is a microcomputer being used by the beachmaster on amphibious operations or by the loadmaster on airlift operations. Other VHSIC applications impacting on logistics requirements would be in the use of encrypted signal devices attached to vehicles that would provide real-time information on location, speed, direction, and even fuel levels. Other areas for refined application are in the use of VHSIC components in microprocessors used in equipment maintenance. These applications are not limited only to ground equipment. Aircraft, ships, and submarines can employ microcomputers utilizing VHSIC chips that will provide vast amounts of logistical data in real-time basis.

5. Other Areas for VHSIC Application

The application of VHSIC components to robots which could be utilized in minefield negation work is waiting exploitation. VHSIC devices will be utilized in subsystems that will permit the use of remotely piloted ground vehicles to conduct reconnaissance and collect data. The moon buggy demonstrated the possible application of RPV's or programmed vehicles to conduct certain missions in ground combat roles.

The utilization of VHSIC components in a general purpose *video processor* is an excellent capabilities enhancement area. There is a need to improve imaging systems such as TV, imaging infrared, and imaging radar for tactical weapons application. A large number of infrared, electro-optical, and radar imaging systems are under development for introduction during the 1980's. Many of these systems will provide image output in the form of television displays; thus they will have a common signal format. This will be an opportune candidate for VHSIC application. This general purpose video processor could be used in trackers for passive missile guidance, pattern recognition and classifiers for tactical aircraft FLIRs and imaging missile systems, image difference processor for vidicon cameras, and anti-jam video data links. It is feasible that every tactical imaging system could employ this general purpose video processor made with VHSIC devices.

VHSIC technology will answer the questions of what information a tank commander needs, in what format he needs it, and what type of device he desires to display this information. VHSIC, combined with VLSI will reduce the size of computers and data processors so that weight, power and size will no longer be constraints in providing what information a tank commander needs. VHSIC will force the question of how much information is needed. The tank commander will no longer wonder what is going on over the entire battlefield, but will be able to make decisions, based on real-time information, as to what course of action to take. VHSIC will also provide him with a decision support system to aid him in making decisions.

On the battlefield one of the critical needs is to disperse the command post. In a highly mobile situation where the units need to be small in size and the concentration of communications system must be reduced, VHSIC components can be applied to existing systems and future systems and allow the command and control elements to be spread over a much greater area. VHSIC size, weight, power reduction and increased capacity features employed in systems will allow tactical deployment structures to be altered or revised to meet high mobility requirements.

D. SUMMARY

VHSIC can be applied to air, sea, and ground platforms. It can enhance the capabilities of almost all systems either directly or indirectly. The potential of VHSIC technology is so great that unless there is a radical change in acquisition policy, the technology will be obsolete before its capability enhancing applications can be maximized.

The application of VHSIC technology will advance lethality, target acquisition, and mobility to such a state that combat intensity will be unparalleled in the history of warfare. The management of the future battlefield will go beyond C^3I. It will require a total integration of all subsystems of the battle system. The coordination of ground and air operations in this scenario will require the integration of resupply, reconstitution, and other activities and assets, if the potential of the combat force is to be optimized. VHSIC technology and its capability enhancing applications provide a solution to tactical and technological demands of the future battlefield. Not only will VHSIC enhance the operational capabilities of systems but it will drastically impact on the maintenance of the electronic subsystems of the military systems. The next chapter will provide an examination of the impact of VHSIC technology upon the maintenance of systems and subsystems.

IV. VHSIC'S IMPACT ON MAINTENANCE

A. BACKGROUND

The one area in which the U.S. has a real technological advantage over the Soviet Union is in electronics and particularly in microelectronics, according to Dr. Edward Teller. Numerous defense personnel and many academicians say the only edge the U.S. has on its major adversaries is in technology. The U.S. depends on it to provide an edge in capability and also in operational readiness.

The demands and requirements to fulfill the military missions of U.S. forces have increased the complexity of systems and equipment at an astonishing rate. Advances in hardware and software technologies are continuing at a rapid rate. Is the advanced electronic technology being utilized in systems too complex for military personnel? This question is being asked inside and outside the military. VHSIC technology promises to provide a solution to the complexity problems. VHSIC technology, through technology transparency, combined with the fact many maintenance procedures previously handled by software can be placed inside the equipment, will reduce much of the maintenance complexity problems.

Even though the reliability of the individual electronic components has steadily improved, when comparing transistor to tubes and IC's to transistors, over the years the complexity of military electronic subsystems has grown even more rapidly. This has created escalating performance demands. The result has been, for several reasons, that the overall failure rate of aircraft avionics systems has increased to the state that unscheduled maintenance of electronics has become a major cause of operational downtime [Ref. 12].

The U.S. defense posture is built around using superior technological capabilities as a force multiplier to offset the quantitative advantages of its adversaries. This is being challenged in two areas: one, the Soviets are making rapid advancements in military technologies, especially microelectronic technology; two, the increasing operational readiness problems associated with complex electronic systems. These problems are illustrated in data showing: U.S. military aircraft are mission capable; that is, in fighting condition, only 1/3 to 2/3 of the time; that up to two man-weeks of maintenance may be required after every sortie; and that the first failure occurs roughly 12 minutes into the flight [Ref. 13].

One of the major arguments today is that increasing weapons complexity reduces combat readiness. The following are ways that the weapons complexity could reduce availability:

1. Degrades combat skills by causing inadequate and unrealistic training
2. Increases reliability and maintainability problems
3. Increases cost of maintenance
4. Increases dependence on large vulnerable support base
5. Increases economic inefficiency of plans
6. Slows modernization by increasing development/ procurement lead times
7. Multiplies magnitude and likelihood of disaster
8. Increase vulnerability to countermeasures
9. Cuts forces, supplies, and munitions to inadequate numbers [Ref. 14].

The complexity of new systems is growing faster than the military's ability to operate and maintain them. In a report by General Walter T. Kevin entitled "Man/Machine Interface - A Growing Crisis," it was concluded that the Army does not have enough qualified people to perform the tasks required to effectively operate, support, and maintain its systems [Ref. 15]. There are reports about the Army, Navy, and Air Force that indicate that the volume and complexity of required data may exceed the analytical ability of operators and maintenance personnel. These reports also suggest that these complexity problems would be magnified under the pressure of combat situations. An example is a U.S. Army Training and Doctrine Command report by Juri Toomepuu in 1981 [Ref. 16].

Because of the very nature of technology it is doubtful that there will be a decrease in the complexity of systems in the near future. In all probability the complexity will increase at a faster pace. Technology is advancing at an ever increasing pace and weapons designers logically take advantage of technology, making systems and equipment more and more sophisticated. As a result of the advanced systems the U.S. has more advanced defense and offense strategies which in turn complicate future military systems. The cycle results in systems that perform complicated tasks, are complex in design and assembly, and difficult to operate and maintain. As the systems increase in complexity, there is a similar increase in the skills required to operate and maintain them.

Electronic maintenance requirements are increasing in a qualitative manner. This is a result of the increase in the number of systems, the increased performance, and the increased size and complexity of installed electronic systems. The advances in electronics technology particularly have brought drastic changes in military hardware and the corresponding need for military personnel with high cognitive abilities.

The U.S. Comptroller General in report number PSAD-81-17 of 29 January 1981, on weapons complexity, found that "...

while these (weapons) systems may have capability to perform their mission, it is often of little value because not all of the systems can be adequately operated, maintained, or supported" [Ref. 17].

The above has established that we must improve defense systems logistics, specifically in the areas of availability, reliability, and maintainability. This includes the need for built-in test (BIT) and for systems with improved fault tolerance, reliability, and repairability. System complexity, combined with the decrease in trained technical personnel, clearly demands that we move toward systems which are more reliable. BIT techniques that provide fault location, so that technicians without a great deal of training can make repairs in a timely manner, are paramount in future systems.

B. RELIABILITY, AVAILABILITY, MAINTAINABILITY

The terms reliability, maintainability, and availability are widely used in regard to electronic systems. The effectiveness of an electronic system is a function of its availability (operational readiness) as well as its performance characteristics. Availability, in turn, depends upon the reliability and maintainability of the systems elements. Reliability is incorporated by the nature of materials and electronic elements utilized and by aspects of design which minimize the systems failure rate.

Maintainability is incorporated through design features which expedite restoring the system to operating condition. Both reliability and maintainability affect the operational readiness of an electronic system. The more reliable the system, the less often it requires maintenance; the more maintainable the system, the less time and effort is required to perform maintenance, and the quicker the system returns to the fully operational mode.

To provide a context for the above and following discussions on military electronic systems maintenance and VHSIC, it is important to have a common understanding of the terms availability, reliability, and maintainability (RAM).

Availability (operational readiness) of a system is a measure of the degree to which a system is in the operable and commitable state at the start of the mission when the mission is called for at an unknown (random) time (inherent availability). It is a function of operating time (reliability) and downtime (maintainability) [Ref. 18].

Reliability is defined as the probability that a system, subsystem, component, or part will perform a required function under specified conditions in a satisfactory manner for a given period of time. It is considered to be the unavailable mean time between events that causes the system to fail [Ref. 19].

Maintainability is defined as a characteristic of design and installation expressed as the probability that an item will be restored to a specified condition within a given period of time. It is a measure of the ease and rapidity with which a system can be maintained, and is measured in terms of the time required to perform maintenance tasks. System maintainability is often expressed in mean-time-to-repair or restore system, maintenance manhours per flying hour, or mean downtime [Ref. 19].

Testability, one of the major disciplines which allows you to meet the maintainability goal, is defined as the inherent capability of a design to allow, as fast as possible, the determination of operability and to provide the visibility to detect and isolate malfunctions [Ref. 20].

The above definitions are used in the following examination of VHSIC'S maintenance impact. There are many schools of thought on the meaning of these terms. For the purpose of this thesis the utilization of these terms is in the above context.

C. CURRENT MILITARY ELECTRONIC MAINTENANCE CONCEPTS

The maintenance concepts of the military services vary between and within the respective services. These concepts range from the lowest level, organizational, to the highest level, depot. A variety of test and repair procedures exist at levels in between. The Army has organizational, direct support, general support, and depot levels. There are similar levels of maintenance for Air Force systems ranging from on-aircraft through flight line and shop-to-depot level. The Navy also has its own version of these maintenance levels, which range from shipboard to depot. The Marine Corps has levels similar to the Army and Navy.

There exist various approaches to electronic systems repair within the services. In some instances, a fault may be isolated to a particular module and the module is replaced at the organizational level. On the other hand, the entire assembly of modules may be replaced at the flight line and the module replacement is evacuated to a direct support level shop.

Once this module is evacuated what happens to it also varies with the individual service. Under the Navy Standard Electronic Module Program (SEM), a failed module may be repaired or thrown away depending upon the cost of the modules [Ref. 21].

The military maintenance approaches vary from service to service and also within each service. The current concepts require high personnel skill levels and a vast amount of Automatic Test (AT) and repair equipment to support these approaches. The next section considers these maintenance concepts in relation to technology trends in electronic systems maintenance.

D. INTEGRATED CIRCUIT TECHNOLOGY TRENDS

The reliability and maintainability characteristics of evolving integrated circuit technologies is of prime importance to the military logistician. The requirements to improve operational readiness can be partially met by deploying more reliable electronic systems.

Increased maintenance and decreased availabilty are not inherent in complexity, as has been suggested by many. This has been proven with integrated circuits. As chip capability has increased from several transistors to tens of thousands of transistors, the reliability of the chips have remained nearly constant. Once a system can be placed on a chip, which VHSIC will do, it will become extremely reliable. Most of the availability problems with high technology weapons systems can be attributed to the proliferation in the number of parts, in the system software, and in the interfaces. These problems were actually brought about by the system design and architecture, and not the complexity or sophistication of the system itself [Ref. 12: p. 6].

Electronic systems reliability and maintainability can be enhanced drastically through redundancy, according to James Clary of Research Triangle Institute. He also says that a key to achieving highly reliable and maintainable systems is redundancy management.

To achieve high system reliability one of two basic or fundamental approaches can be used. One approach is to build a system made up of high reliability components. The other basic approach is to use redundant systems resources. The increased availability of high-density integrated circuits now make it feasible and economical to drastically enhance system reliability by the redundancy approach. This approach has been demonstrated in the space program. Now with VHSIC and VLSI the methods that are used in the space systems can also be applied to military systems used in ships, aircraft, and ground equipment.

These highly reliable electronic systems when combined with a health and readiness monitoring capability will allow a "maintenance-free" mission environment. Scheduled maintenance will become the policy; that is, a system will be deployed without maintenance for an operation and when returned it would be serviced. This type of scheduled maintenance concept in electronic systems has not been feasible in the past. Utilizing today's developing microelectronic technology such as VHSIC and VLSI systems can be designed to be fault-tolerant. This will allow faulty system components to be replaced at regular service intervals, better known as scheduled maintenance in this context. This approach will alter maintenance practices and concepts and provide near 100% availability of electronic systems. This scheduled maintenance concept will cause the operational readiness of electronic systems, and in turn systems to be far higher than before [Ref. 22].

Redundancy will also enhance maintainability. Testability, which helps to achieve the goal of high maintainability, will be improved through the use of redundant, on-chip circuits which provide on-line visibility into the functional processes of systems composed of these devices. This will be demonstrated by the use of a built-in-test approach. Automatic Testing on-line and off-line will be greatly impacted by the rapidly evolving integrated circuit technologies.

E. VHSIC'S IMPACT ON RELIABILITY, AVAILABILITY, MAINTAINABILITY

As presented above, the availability or operational readiness of a system is a function of reliability and maintainability. Also presented earlier in this chapter are the present problems related to RAM in our military electronic systems. The preceeding section presented technology trends in regard to RAM and electronic systems. The VHSIC program provides a solution to these issues in a systematic and unified manner. VHSIC will bring substantial reliability enhancement in electronic systems by the extra computing power it will provide.

As pointed out previously an approach to higher reliability is through redundancy and fault tolerance. VHSIC combined with VLSI will provide vastly more built in redundancy. It will also provide chips excess computing power to detect and diagnose their own malfunctions and to execute autonomous preprogrammed corrective measures to cover nearly any contingency. The electronic systems will be able to test themselves, detect faults and reconfigure their chips, or even portions within chips, while continuing to function.

Another VHSIC impact on reliability will be the fact that systems utilizing VHSIC components will contain fewer major sources of component failures, such as power chips and external connections. As large assemblies of components are placed on a single chip there will be a vast improvement in reliability, because the major failure in electronic systems is related to the connection and number of connections of components, not the component itself. The increased reliability of VHSIC due to the reduction in the number of components, will reduce unscheduled maintenance which is a major reason for lost operational time in many systems [Ref. 23].

VHSIC's health and readiness monitoring capabilities provided by assigning circuits and software for on-chip testing and diagnosis of functions or circuit parameters will also enhance reliability. The on-chip test circuits will monitor and predict long-range reliability problems. This will include built-in moisture sensors to monitor hermetic seals, oxide capacitors to monitor the stability of oxide insulators, and counter circuits to measure degradation in performance [Ref. 23: p. 78].

Maintainability, the other half of the two major factors in operational readiness, also will be greatly affected by VHSIC. High testability, which is a major feature of VHSIC, is the major way we achieve high maintainability. The testability improvements of VHSIC will be a marked improvement over the current Automatic Testing approaches of electronics systems. The BIT feature of VHSIC, in conjunction with its high gate and switching density, will allow many more test points in systems. This, when combined with the fact that most of automatic testing that is presently handled by software can be built into the equipment, will bring about much higher accuracy in fault isolation. When the equipment is non-operational, VHSIC BIT features, with their fault detection and fault isolation, will simplify the diagnostic problems common to present trouble shooting techniques.

F. SUMMARY

VHSIC technology will bring about radical improvements in electronic systems and, in turn, systems availability. The high integration level of VHSIC can bring about a 10 to 100:1 improvement in reliability. The built-in-test features of VHSIC will have a marked impact on testability and will greatly simplify maintenance procedures and will result in higher maintainability of systems. The fault-tolerance designs of VHSIC components will offer another order of magnitude of improvement in reliability of systems. The synergistic effects of VHSIC's impact on reliability and maintainability will bring about changes in maintenance concepts and will drastically affect logistics requirements for electronic systems and systems that utilize integrated circuits in their subsystems.

V. DISCUSSION

A. GENERAL

The importance of logistics to military operations has been established. There are many classic examples where logistics support or the management of material on the battlefield was the decisive factor in the outcome of battles and wars. Hannibal, Hitler, and Napoleon, to mention a few, all had logistics problems that proved to be a major contributing factor to their defeats.

The following quotes of several major military thinkers provide a historical perspective of logistics and emphasize its importance over the years:

1. "Logistics comprises the means and arrangements which work out the plans of strategy and tactics. Strategy decides where to act; logistics brings the troops to this point." Jomini: Precis de L'Art de la Guerre, 1838.
2. "Mobility is the true test of a supply system." B.H. Liddell Hart: Thoughts on War, iv, 1944.
3. "The soldier cannot be a fighter and a pack animal at one and the same time, any more than a field piece can be a gun and a supply vehicle combined." J.F.C. Fuller: "Letter to S.L.A. Marshall," c. 1948.

4. "In our day wars are not won by mere enthusiasm, but by technical superiority." V.I. Lenin: "Speech, 1918."

5. "What I want to avoid is that my supplies should command me." Comte de Guibert: Essai General de la Tacticque, 1770.

The above quotes illustrate how logistics is regarded in terms of tactics and strategy. They also illustrate that logistics has been challenging military leaders for many centuries. The challenge will become even greater as the complexity of systems continues to grow and as the two basic elements of tactics, protection and mobility become more critical for future military engagements.

As the "Art of War" has evolved over the history of man and man's weapons to do battle have become more complex, the logistics support trains they have created are hard to comprehend, let alone run. The ratio of actual combatant personnel to the total number in the armed forces has gradually reduced, so that the profession is now composed mostly of support personnel. Efforts and energies must be directed at reducing these logistical trains and manpower requirements associated with them for a variety of reasons, primarily because of the costs of the trains and the projections showing a progression toward quality and quantity shortages of military personnel. Future systems must be designed and developed with an intent to have machines do more functions and require less logistical support.

Dr. Edward Teller presents a viable approach to solving some of these logistical problems. He says that the main idea behind today's manned military equipment is life support systems. As a result the equipment is more bulky, more expensive, and less expendable. Systems with remote controls and without on-board operators must be perfected. Microelectronics has made feasible smaller more capable and more reliable systems, so that unmanned devices can now be expendable and less expensive. The electronic devices can outperform the human being in the observation and transmission of data anytime [Ref. 5: p. 38]

Logistics is of major concern in any combat zone. Any technology which helps to make logistics easier, less costly, more reliable and less demanding of personnel quality and quantity during conflict and can also improve operational readiness, can have a major impact on the outcome. Potential for tremendous advancements in these areas is now available in the microelectronic technology known as VHSIC and VLSI.

The future battlefield is projected to be one of awesome lethality, high mobility, and covering large areas. The military must balance the issue of power and movement, while not sacrificing either.

An opportunistic approach is available in the integrated circuit technology presently developing. The devices and components that are produced as a result of the VHSIC program should make available to military strategists and tacticians systems that will meet the fighting power, mobility, and range attributes required for an effective and efficient military force on the battlefield of the future.

B. IMPACT OF VHSIC TOWARD LOGISTIC CAPABILITY ENHANCEMENT

The application of VHSIC devices will greatly enhance the capabilities of many systems as presented in chapter 3. As a result, major systems will change. Many systems will become subsystems, and subsystems will merge into larger systems integrated into a simple complex or single chip.

The versatility enhancements that will flow from VHSIC will allow many existing and planned weapons and systems to perform multi-missions and multi-functions. Future major systems will be able to perform the functions and missions of previous major systems in their subsystems. A positive aspect is that electronic subsystems cost less than major systems, and with the projected reductions of major systems into subsystems, potential for the addition of capabilities is enhanced. This has a two-fold advantage. First, resources previously allocated to major systems can provide additional capability by the acquisition of more subsystems. Second, the logistic support for those previous major systems will be reduced drastically or removed entirely. For example, the entire package of ASW equipment of a S3A Viking aircraft could be packaged into a pod and placed on several different aircraft and controlled from a single monitor aircraft or from the ground. This is only one example of how VHSIC would drastically reduce inventory requirements of costly systems and their logistic requirements for material and personnel.

The direct and indirect impact of VHSIC products on the lethality and accuracy of "smart" and "dumb" munitions will bring about a reduction in the number needed and in turn a decrease in the logistics support required for these munitions. The direct impact in precision guided munitions will be that fewer rounds will be required. The more accurate and more lethal the weapons, the less number will be needed and, as a result, there will be less inventory to transport, maintain, and manage. This is a vital point for the mobile battlefield of the future.

The size, weight, and power reduction features of VHSIC devices and components will allow major reduction in equipment needed to transport and support systems. For example, batteries for man-packed radios will be drastically reduced in size and weight. This will not only reduce the logistics burden for the individual but will impact notably on the burden for the entire logistics system.

In the future, there will be the replacement of manned equipment with unmanned equipment made possible by the application of microelectronic technology. This will impact in numerous ways. Specifically, there will be smaller less expensive systems and the potential for reduction in the loss of life with unmanned vehicles and equipment. The application of VHSIC related devices to RPV's and ground vehicles will result in reductions in present support personnel and logistic requirements leaving room for as yet unknown new military devices. VHSIC's lightweight and low power requirements make it ideal for operating on the battlefield. Not only will transportation to and from various places be easier and cheaper, but in many cases, a weapon system or support system could be carried by an individual.

One of the major problems facing the military today is the quality of the operator and maintenance personnel to operate the complex equipment. The application of VHSIC products has the potential for the utilization of technology to make the operation and maintenance of equipment much simpler. The much needed approach of technology transparency will be a major advancement of VHSIC. A major change is that technology will be used to make complex systems simpler and easier to operate and maintain. This is vital because of the stress and pressure that is present when performing under battle conditions. The improvement of man and machine interface resulting from the products of the VHSIC program will increase the confidence that operational and maintenance personnel will have in themselves and their equipment. This will be a contributing factor in reducing the stress and pressure of combat.

The data and signal processing impacts of VHSIC products on battlefield logistics information systems will be in providing operating information on a real-time basis. VHSIC related products will improve the accuracy, detail, type, and scope of logistic information that will be available on the future battlefield. This will impact greatly on tactical decisions and the course of action to gain victory in battle. VHSIC, through its capabilities enhancement, will have a marked impact on material management in the battle zone. In the area of logistical data automation and processing speed capabilities, VHSIC will result in systems that will provide real-time information to the battlefield logistician, allowing more timely decisions to support the commander's high mobility tactics. Unmanned equipment made possible by microelectronic technology provides the potential for operation in spite of weather conditions. In fact, it makes possible the potential for use of inclement weather conditions as a major offensive weapon.

C. VHSIC'S MAINTENANCE IMPACT ON BATTLEFIELD LOGISTICS

VHSIC will provide a new level of availability, reliability, and maintainability to battlefield systems. One of the key advances of VHSIC in logistic areas will be in the reduction of supply and maintenance personnel required in the battle zone. The major increase in both static and dynamic reliability will greatly reduce equipment failures, yet still maintaining the advanced performance levels. With the high reliability and maintainability expected from VHSIC equipped products there can be a reduction in support personnel. In fact, there are many indications that VHSIC will bring about a change in the levels of maintenance being performed on the battlefield. There is strong indication that a two level maintenance concept will be present as a standard for electronic systems maintenance. Analysis as to what levels of maintenance should be implemented as a result of VHSIC impact on maintenance is needed. However, there are strong indications that VHSIC will decrease the complexity of maintenance and supply providing space for increased scope of operations.

The maintainability and testability improvements of VHSIC will be seen in the more efficient aspects of repair and the reduced number of operational spares required. The BIT attributes of VHSIC will speed the identification and location of a failure in comparison to existing techniques.

BIT maintenance concepts will reduce manpower requirements, increase operational readiness, and reduce life cycle cost. The maintainability impact will also be seen in that equipment will be returned to operational status much faster. Thus inventory levels could be reduced. If a system can be returned to service in shorter time, the requirement for backup systems will be reduced.

Another major maintenance impact of VHSIC will be the providing of critical information for maintenance and operator personnel. It is often important to provide the operator and maintenance personnel with technical instructions. This can be provided for equipment by microprocessors and microcomputers utilizing VHSIC components. These devices will be in the form of built-in subsystems reducing drastically the publications and technical manuals required on the battlefield.

Spare parts and material requirements normally decrease with an increase in the reliability of the parts used in equipment. This decrease is usually a direct result of reducing the frequency of failures and thereby reducing the number of spare parts required to maintain a system's operational capability. Redundancy will permit repair without part stockage in those self-repairing devices. VHSIC will make a ' ɩable impact on the battlefield requirements for spares and materials as a result of its direct and indirect increases in systems reliability.

Another impact of VHSIC in the maintenance area is that VHSIC technology with its inherent reliability and ability to host a large amount of built-in logic can open new ways of training and maintaining the proficiency of operator and maintenance personnel. This will have a major impact on training concepts. VHSIC products will open up a whole new approach to training equipment for operational and maintenance personnel. This will increase the capabilities to maintain maintenance support personnel in a higher state of readiness through higher proficiency. This in turn will impact in a higher operational readiness of the combat systems and forces.

The major impacts of VHSIC on maintenance can be focussed and summarized in three areas. One, VHSIC will bring about reductions in maintenance and supply personnel required on the battlefield. Two, VHSIC will bring about direct and indirect cost saving and, as a result, more resources can be allocated to the acquisition of more systems and subsystems. Three, and perhaps the most important area, is in operational readiness of systems. The reliability and maintainability features expected from VHSIC will have a major positive impact on the operational readiness and availability of systems on the battlefield.

D. VHSIC AND BATTLEFIELD MATERIAL MANAGEMENT

The impact of VHSIC technology on battlefield material management will be observed in the simplification, expansion and cost reduction of material management.

The systems will be more reliable, often with expendable components. The munitions will be more effective and efficient. As a result the battlefield logistician can work with a better flow and smaller inventory of material.

The maintenance of systems will be reduced because of higher reliability and maintainability. The amount of non-operational equipment will be reduced as will the spares to replace and repair them.

VHSIC chips and devices have the potential to provide the technology to effect self-repair through circuit redundancy, to allow for BIT, and to maintain reference information such as configuration, parts list, maintenance check-off list, organization level instructions, and/or maintenance history. Also, the potential application of VHSIC technology to support equipment can provide maintenance aids, data management, training development and task simulation. The potential built-in artificial intelligence can result in reduced maintenance time, reduced support personnel requirements, reduced maintenance proficiency requirements and, in turn, reduced maintenance related failures.

The management of material on the battlefield will be greatly enhanced by the application of VHSIC products to computerized equipment. This will allow automation of logistics data down to the lowest support unit in combat. It will provide real-time information that will facilitate the efficiency of material distribution on the battlefield. It will allow the logistician to put the desired items at the correct location at the correct time in a higher state of readiness.

VI. SUMMARY, CONCLUSION, RECOMMENDATION

A. SUMMARY

The management of material on the battlefield of the future possibly presents military logisticians with their greatest challenges to date. Problems related to the availability, reliability, maintainability, and life-cycle costs of military electronic systems are hounding the military establishment. GAO reports are frequently reminding the military of the above problems and recommending that corrective action be taken immediately. To further complicate these problems, the military is experiencing quantitative and qualitative problems with personnel. It appears that military systems technology with its ever increasing rate of complexity, is on a collision course with the projected shortage of analytically capable military personnel to operate and maintain its products. Indications of Soviet technological advancements in military electronics, as well as in other areas, also are posing additional challenges to the military establishment.

The utilization of technology as a force multiplier has become the basis for development of future systems. Development tactics call for highly mobile units, smaller in size, and dispersed over large areas.

The combat intensity of future battles will be high. This will stem from improved weapon lethality, increased target acquisition capabilities, and projected improvements in mobility promised by the next generation of battle systems.

Battle management in the battle zone of the future will be critical. The technological advances in lethality, target acquisition, and mobility will require more timely intensive management and coordination of combat and support activities on the battlefield of the future.

Battle management of the complex interrelations between tactics, forces, and technology will be much more than just command, control, and communications. It will require the integration of logistics into the battle management system on a much greater level than ever before.

B. CONCLUSION

The VHSIC program has the potential to resolve many of the challenges presently facing the military logistician in regard to the management of material in the battle zone.

The deductive and inductive impact of VHSIC technology will permit almost unlimited development of applications in battle zone material management command and control.

The potential enhancement of systems capabilities offered by VHSIC technology can dramatically facilitate the battlefield logistics process. The direct impact should be observed in the reduction in volume, size, and weight of material to be managed in the battle zone. The indirect impact of capabilities enhancements will be observed in the application of VHSIC technology to the material management problem itself. VHSIC offers the capability of real-time logistical information for the battle zone logistician.

The potential reliability, maintainability, availability attributes of VHSIC technology can provide new levels of operational readiness for combat systems.

VHSIC technology offers a solution to many combat logistical problems. It is not the solution to all problems but it will have a pronounced effect on the way we conduct material management in the battle zone. The manual processing of supply orders to the supply depot has been superceded by computerized requisitioning and status reporting systems of today. The Conestoga Wagon has given way to the Space Shuttle. The possible impact of VHSIC technology on material management in the battle zone of the future can produce some equally spectacular results.

C. RECOMMENDATION

This thesis has examined VHSIC technology's impact on battle zone material management with a primary focus on the enhancement of systems capabilities and maintenance. This technology has awesome potential for application to military systems. Additional research in the following areas is recommended:

1. Identify the most productive ways of impacting VHSIC design and applying VHSIC technology to improve the efficiency and effectiveness of logistics support.
2. Examine ways to introduce VHSIC technology into the military in a highly productive way at the earliest possible time.
3. Examine specific logistics applications of VHSIC to determine if standard chips offer a better time/cost trade than custom VHSIC chips.
4. Analyze the impact of VHSIC on the life cycle costs of military electronic systems so that planners of the VHSIC program may allocate appropriate limited resources to the development of VHSIC technology.
5. Determine how VHSIC technology can be employed to improve the current logistic problems of manpower skills and quantities, maintenance cost, and operational readiness.
6. Examine the impact of VHSIC technology on the conventional three levels of maintenance.
7. Analyze the potential changes in military logistics introduced by VHSIC technology insertion and their impact on operations and maintenance costs.

8. Examine the impact of VHSIC technology on the training and proficiency of operator and maintenance personnel.
9. Analyze the impact of VHSIC technology on the obsolescence issues of military electronics.

APPENDIX A

GLOSSARY OF TERMS AND ACRONYMS

ACRONMYS

AMRAAS	Advanced Medium-Range Air-to-Air System
ASOP	Advanced on-board Signal Processor
ASW	Anti-Submarine Warfare
BIDS	Battlefield Information Distribution System
BIT	Built-in-Test
DAST	Design Architecture Software Testing
DOD	Department of Defense
ESM	Electronic Support Measures
EW	Electronic Warfare
FLIR	Forward Looking Infrared
IC	Integrated Circuit
IDA	Institute for Defense Analysis
JTIDS	Joint Tactical Information Distribution System
LCC	Life Cycle Cost
MTBF	Mean Time Between Failure
MTTR	Mean Time to Repair
M^2F^2	Multi-Mode Fire and Forget
NAC	Naval Avionic Center
NADC	Naval Air Development Center
NOSC	Naval Ocean Systems Center

NWC	Naval Weapon Center
PLRS	Position Location Reporting System
RAM	Reliability Availability Maintainability
RPV	Remotely Piloted Vehicle
SEM	Standard Electronic Module
VHSIC	Very High Speed Integrated Circuit
VLSI	Very Large Scale Integration
VLSIC	Very Large Scale Integrated Circuit

TERMS

Availability. A measure of the degree to which an item is in the operable and commitable state at the start of the mission when the mission is called for at an unknown (random) time (inherent availability). For OT&E purposes, availability is considered synonymous with operational readiness.

Built-In. Of an accessary feature of capability incorporated in a piece of equipment or logistic system.

Chip. A circuit integrated on a small piece of semiconductor material that is capable of performing from a small to a significant number of functions.

Clock Rate. The rate at which a word or characters of a word (bits) are transferred from one internal computer element to another. Clock rate is expressed in cycles per second.

Gate. A group of active and passive elements capable of performing a single logic function (e.g., and, or, nand, nor).

Integrated Circuit. An interconnected array of active and passive elements integrated with a single semiconductor substrate or deposited on the substrate by a continuous series of compatible processes.

Level of Integration. The number of gates per chip or IC.

Lethality. The capacity to cause death, grave damage or destruction.

Logistics Support. The supply and maintenance of material essential to proper operation of a system in the force.

Maintainability. A characteristic of design and installation expressed as the probability that an item will be restored to a specified condition within a given period of time when the maintenance is performed using prescribed procedures and resources.

Material Management. Direction and control of those aspects of logistics which deal with material, including the functions of storage, distribution, disposal, maintenance; encompasses material control, inventory control, inventory management and supply management.

Microcomputer. A computer whose major sections - CPU, control, timing, and memory - are contained on a single, integrated-circuit chip, or at most, a few chips.

Microelectronics. The entire body of electronic art which is connected with or applied to the realization of electronic systems from extremely small electronic parts. Somewhat synonymous with integrated circuit.

Microprocessor. A computer contained on as few as three chips, which functions as central processor for executing instructions, a volatile memory for storing data, and an interface unit through which data and instructions are transmitted.

Mobility. A quality or capability of military forces which permits them to move from place to place while retaining the ability to fulfill their primary mission.

Modem. A device that modulates and demodulates signals transmitted over communication facilities.

Module. A part, assembly, or component which is designed to be handled as a single unit to facilitate supply and installation, operations and/or maintenance. It can be either repairable or nonrepair (throwaway).

Operational Readiness. The capability of a unit, ship, weapon system, or equipment to perform the missions or functions for which it is organized or designed.

Reliability. Probability that material will perform its intended function for a specified period of time under stated conditions.

Throughput Rate. The highest rate at which a multiplexer can switch from channel to channel at its specified accuracy.

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